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Anthropometric Program Analysis

of

Reach and Body Movement

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August 14, 1981

ABSTRACT

This was a multifaceted project involving several tasks related to anthropometric data collection and comparison.

Such data occurred in various forms, and included activities relating to human force and motion capabilities. Information was obtained from astronaut candidates doing certain force and motion activities. These individuals were suited, both in one-G and in neutral buoyancy of a water facility, and also unsuited, in a one-G environment.

Also involved was the review and comparison of several pieces of hardware used in quantification of the data collection. This hardware included a CYBEX II force and torque machine, and a three-dimension camera system(AMS) for measuring range of motion envelopes.

Preliminary comparison of collecting techniques was made to determine significant variables in the available data. Also, suggestions are offered for standardization of data collection in an attempt to better predict usefullness to various groups.

ACKNOWLEDGEMENTS

I wish to respectfully give my thanks to the following experts who gave so freely of their time and understanding to make this project a success: Dr. James Lewis, Head of Crew Station Design Section, encouraged me and helped direct me and focus my objectives. Also, Barbara Woolford, who patiently explained the mysteries of the computer software programs. My gratitude, especially, to Mr. John Jackson who hand-carried many references, introduced me to many other important people and helped me see the finer points to anthropometrics.

I am also grateful to the many others who let me into their facilities and labs, gave me special tours of the work stations and allowed inspection of WETF water tank. Without these, the job would have been impossible.

C. J. M.

INTRODUCTION:

It has long been recognized that the science of measurement has been important in the history of civilization. Even in our present-day technology, we easily forget this principle as it applies to the physical size of a person and his ability to function in our complex world.

Early researchers into body size, like Blumenbach (1752-1840), reported for the first time the complete body measurements. At about this same time the statistician Quetelet (1796-1874) carried out the first large-scale body measurement study, and is recognized as founding the science and coining the term "anthropometry".

Later, during the early part of the 20th century, extensive and rapid increases in anthropometric literature occurred. At this time, difficulties became evident as various investigators used differing terms in gaining measurements on the human body. More and more, knowledge of methodology became an important part of data interpretation and evaluation.

Today, what most people consider "normality" of body size is more accurately replaced with tables and charts of statistical values. In anthropometry today, statistical calculations are used to establish design criteria for specifying the range of each body dimension or function for which a product is to be designed.

These criteria will also determine the basis for selection standards used in screening a potential user population. This setting of anthropometric criteria or limits is essential if we are to insure proper fit of the man-machine system. However, we must recognize that variables of human beings are vastly different than those of machinery.

In both cases, too tight a tolerance excludes use by many, and may well raise the costs. On the other hand, a design that accommodates the full range of observed variations in the population, requires adjustments to the design, and will also raise the costs.

PROBLEM:

As in many engineering problems of measurement, the most direct approach to movement and range of motion capabilities is that of defining "final effects". At this level of the problem, the desired answer can be presented in a simple "yes" or "no" to a question such as: "can the individual reach and move a control?"

Given no prior knowledge, the likely approach to such a problem is to build a mockup of the situation and test a sample of individuals to observe if they are able to perform the given task.

This approach has its obvious limitations. After the answer is obtained, one still has knowledge of only a single, specific situation that may never be repeated.

At the next level, a more general solution may be sought in terms of defining a reachable spatial volume by determining its boundry surfaces, or its envelope. Within this defined envelope, several motion activities are possible.

Angular movement measurement is one of these, and has much in common with measurement of linear dimensions. Here, a variety of types of information regarding movement, may be obtained. These include centers of rotation and angles as well as range of movement envelopes.

In each of the foregoing, for angular movement, a consistent use of scales, reference axes, planes and vectorial representation of links will reduce uncertainty and encourage consistency. These are important in that they will lead to more accurate design data and the development of clear specifications for mobility requirements.

In the cases involving dynamic recording and measurement of human movement, several measurement problems are compounded. According to J. A. Roebuck (1975) and others, the following are the minimum requirements for exact and objective methods of recording human movement:

1. Constant relationship and precision to the given dimension chosen.
2. Action of the subject must be unobstructed.
3. The range and sensitivity of the equipment must be sufficient to record changes in body position.
4. The data should be easily interpreted.

Further, as compared to anthropometric dimensions, strength data generally have a much greater variability between individuals. It also my be more easily influenced by a change in either mental or physical state of the subject.

Therefore, it has been stated that many of the published studies on muscular strength may suffer from shortcomings involving failure to consider the biomechanical, physiological, and the psychological aspects, as well as inadequate or improper instrumentation. This last deficit may also include failure to report clearly the experimental procedures or statistical analyses.

Indeed, one of the most difficult problems in the assessment and application of human strength data is the presentation of this data. For strength data to be valid, a large number of variables must be kept constant. Their status must be clearly specified in the protocol or final report. The failure to specify such experimental conditions has caused the results of many studies to be of questionable validity and use.

CURRENT ANTHROPOMETRICS LABORATORY:

Given the brief background on anthropometrics and some of the recognized problems associated with the field, the present task at the Johnson Space Center and the Anthropometrics Laboratory (AML) may now be undertaken.

The primary concern was analyzing the usefulness of the AML facility in determining the kinds of problems that a suited astronaut might encounter in E.V.A. Immediate questions which came to the fore were: What information is vital? How can this information be obtained quickly and most accurately? And, what processing is available for the data reduction and analysis?

In order to answer these and other related questions, it became apparent that the task was multifaceted. Other researchers needed to be contacted. Suit facilities had to be seen. Various work stations needed to be visited, to understand how the real world of the E.V.A. could be demonstrated.

Questions as those above needed answers. As the list of "experts" from contacted laboratories grew, the evidence became clear that a large number of researchers were currently applying themselves to the problem of motion and force analysis. (See Table 1.0)

It also became clear that several important differences were present as to techniques and approach to the anthropometrics problem. Many such workers, it was discovered, have unique needs and therefore, have designed their techniques to that purpose. Sports medicine and physical education labs which were contacted had such a special purpose.

In addition, certain private lab facilities for anthropometric collection are available, and will tailor their techniques in an attempt to fit the needs of their clients.

One research unit contacted is using the method of stereo-photogammetry to re-configure the actual body proportions of an individual. These dimensions are then recorded digitally to later be displayed.

Several labs across the country are using two-dimensional and three-dimensional approaches with 16 mm cameras to record motion activities. Such film is later analyzed for angular and reach changes, to be digitized for reference on the test subject.

As noted earlier, the suit facility was a vital factor to further understanding of any motion analysis problems. At various times through the weeks, contacts and meetings were held with individuals of this facility. The attempt was to gain knowledge about the current suit model, with particular reference and attention to its fabrication and intended E.V.A. uses.

Several days were spent observing suited activities by astronauts performing tasks in the WETF water tank. Here, several different astronauts were in training to attempt a number of activities on the submerged shuttle cargo bay and air-lock. Participants were in neutral buoyancy to simulate zero-G effects. General suit flexibility and cuff-ring mobility was observed during these tasks and activities.

At present, the current model of the E.V.A. suit has had only limited pilot runs of anthropometric data collected on it. One such collection was made using a two-dimensional reach onto a drawing board. This was a reach test done in the WETF water tank.

Also, a single demonstration, suited and in one-G was run, using a three-dimensional approach with T.V. cameras and a microprocessor analyzer.

Finally, while several unsuited force and torque measurements have been obtained using a CYBEX force machine, no such information is currently available using the present model E.V.A. space suit.

It is evident that the ability to do work should be the primary tool to evaluate any E.V.A.space suit. And, while it is more difficult to relate elementary force and torque functions to the more complex mission maneuvers, data from such elementary movements may be applied to understand the limits of a given space suit and the occupant within.

The anthropometrics laboratory (AML) at NASA-JSC is dedicated to the task of gathering vital information on reach and force of astronauts in both unsuited and suited configuration. To this end, the AML has several prototype pieces of equipment designed for such data collection. These include:

1. Automatic joint angle measurement device, consisting of a video camera, lights which attach to the subject, and a microprocessor for data acquisition. This system provides for direct angle readings from a joint, plus a hard copy print thru an electronic teletypewriter.

2. Automatic three-dimensional anthropometric video system, including 3 T.V. cameras, a lighting system attaching to the subject, and a microprocessor. Information gained from this system includes envelope of motion and velocity-acceleration. Data from this equipment is programed thru computers for use.

3. A CYBEX II dynamometer and recorder for force and torque data collection. This machine allows analysis of the various body joint movement and several types of motion data, including strength, torque, power endurance and other isokinetics.

When fully operational, the above equipment has the capability of collecting the many parameters of body movement and force data on both the unsuited and suited individual.

Used together, the CYBEX and the three-dimensional system can give information on both envelope of motion AND the type and endurance of many tasks at various body positions.

Clearly, one of the principle jobs in the study of dynamic anthropometry, is to describe quantitatively the translocations and rotations of the various body segments, and to relate them to the movement of the entire body. To be adequate, any such description requires not only that these body movements be measured in three-dimensions, but also that velocities and force be recorded and that the sequence of motion of various parts of the body be determined.

FUTURE SUGGESTIONS:

The Johnson Space Center's AML is currently in the early functional stages to begin collection of useful data on suited and unsuited functional reach and force activities.

A test plan outline has been received from the suit facility, and discussion begun for the start of a performance mapping profile on shuttle SSA suit at various pressure levels. The general procedure will include the following:

1. Establish baseline "nude body" range of movement measurements with selected subjects. Each subject will serve as his own control.
   a) Use document No. ILS-J-SS-011 as a guide line to determine 22 basic body motions required, and the technique for deriving these 22 motions.
2. Conduct suited, pressurized mobility range measurements with three dimensional cameras, using:
   a) above defined 22 motions.
   b) shuttle space suit at following P.S.I.: 4.0, 5.0, and 6.0
3. Repeat steps 2a and 2b, using shuttle space suit without thermal micrometeroid layer.
4. The following cautions are to be observed in each of the above experimental conditions:
   a) Each position to be run three times, with average value of these taken as mean.
   b) Care used not to degrade motions due to candidate fatigue.
   c) Refer to appropriate standard text sources for defining each motion given.

It is further suggested that the suited reach (envelope) information be formatted in the manner given below and adapted from Kennedy (1978).

Using AML three dimension camera system, develop reach envelope in the prescribed manner. Then, for better data availability, determine the outside boundry values of this envelope. This may be done by slicing 15^{o} horizontal layers and 15^{o} vertical layers through the reach envelope. By using a standard reference point (such as SCYE or seat) reach numbers can quickly be obtained in 15^{o} intervals.

To gain further knowledge about a given model suit, additional reach data must be obtained in neutral buoyancy of WETF water tank. Alternative methods are suggested for collecting such data. Perhaps placement of reach boards at front, at 45^{o} each side and 90^{o} each side would give more useful reach data from the WETF tank approach. However, general format must be compatable if these data are to be comparable with the 3-D system.

Additionally, force and work information is vital on each suit. These data must also be obtained in one-G and in simulated 0-G environment.

Suggestions are also made to use Life Sciences Division for coordinating efforts for obtaining B.T.U.'s used and thermal loads developed during standard force and work tasks, while in a given model suit under the varying conditions.

A final reminder that data bases must be developed using as much standardized procedures as can be obtained for proper data comparison in the future.

TABLE 1.0

Laboratories and Individuals
Involved in Anthropometric Studies of
Motion and Force

Ken Kennedy and Chuck Clauser Anthropometric Unit Wright Patterson A.F.B. (87) 775-5779	Date collection on several types of flight suits. Have developed a reach device. Have collected suit reach data. Determined "reach mobility factor" of suits.
Joe McDaniel (with Kennedy) Wright Patterson A.F.B.	Has current project on body size and strength/endurance testing. Has suited data with SR 71 and U2 anti-G garments. Data base from various suited configurations. Data available thru simulator-computer programs. Also tests run for kinetic measurements plus fixed mode.
Dr. Don Sheffer and Robert Herron University of Akron Institute for BioMedical Engineering Research (216) 375-3850	Have data on stereophotogammetric body configurations. I.B.M. cards received by AML as sample of this program.
Dr. Herb Reynolds and Dr. Howard Stoudt Michigan State University East Lansing, MI. 48824 (87) 375-4675 (87) 373-3200	Reynolds is currently collecting 3-D anthropometric data, using stereo X-ray technique. Cadaver use involves placement of metal pellets into joint cavities. Computer fortram program digitizes data. Also doing 3-D postural data on stewardressess.

John McConville Anthropometric Research Studies Inc. 503 Xenia Ave. Yellow Springs, OH. 45387 (513) 767-7226	Has done early studies on volume and center of gravity of various body components. (using cadavers) Presently doing moments of inertia on body segments (cadavers). Has reference to W.P.A.F.B. large data bank, raw data, and various display programs for such data.
Lloyd Laubach University of Dayton P.E. Dept. (513) 229-4225	Currently teaching only. Has had important past involvement in anthropometrics studies.
John A. Roebuck Space Division Rockwell International Corp. 1224 Lakewood Blvd. Downey CA. 90241 (87) (213) 594-3078 or 3311	Publication and familiarity with one and two camera approach on stereophotogammetry. Has no data base on these techniques. Currently on space serve project at R.I.
Jaime Cuzzi Institute for Rehabilitative Research Baylor University 1330 Moursund Houston, TX 77030	Experienced with 3-D body configuration data collection techniques. Helped design program for data collection.
Dr. John Cooper Indiana University at Bloomington. (812) 337-7302	Early work using single movie camera for determining moments of inertia, velocity, acceleration and angles. Currently using two camera (16mm) movies, with frame-by-frame analysis and digitization. Considerable experience with program writing.

Dr. Carol Widule Purdue University at West Lafayette, IN. (317) 494-3675	Past work with Dr. John Cooper. Currently working with 2-D cameras only. Collecting kinematic information for digitization from film frames.
Dr. Mary Dawson Western Michigan University Kalamazoo, MI. (87) 383-1338	Using both 2 and 3-D 16 mm movie data on motion.
Dr. Barry Bates Biodynamics Inc. Box 3157 Eugene, OR. 97403 (87) (503) 428-4118	Has three labs across country; Dallas and Chapel Hill, N.C. Speciality in software; data on sports medicine and joint motion action with CYBEX.
Gideon Ariel Coto Sports Research Cent. (with Vic Braden) 2200Plano Trabuco Canyon Rd. Trabuco Canyon Rd. CA 92678	"Sports training expert".

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